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RESEARCHES ON TRIBOLOGICAL BEHAVIOR OF FOOD POWDERS IN THE FRAMEWORK OF INDUSTRIAL PROCESSING

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1. Generalities

Food industry is a domain of great importance and is continually changing. Food safety is monitored more than ever.

A very important aspect in this continuous monitoring is represented by the transport, depositing and retail of the powders from these deposits.

We find powders in the vast majority of domains of the food industry in the milling industry, in bread manufacturing or sugar products, we deal with powders everywhere, some fine such as low particle size flour, cocoa, paprika, powder sugar, and some with larger particle sizes, such as graham flour, rye flour, corn flour or grounded coffee.

In order to transport and discharge powders without any problems a continuous flow has to be initiated. We have to mention the fact that the flow has to be continuous without any interruptions. In order to obtain a continuous uninterrupted flow we need to know the flow characteristics and apparent density of the respective powders. The fluidity and apparent density of powders depend on more factors, such as: particle size/distribution, humidity, particle shape and aspect of its surface.

Another aspect that has to be taken in to consideration when initiating the flow is determining the shear force. As we see from the experiments carried out so far (1) the shear phenomena appears both between the particles of a powder that is in a state of flow and between the particles and the walls of the container.

We determine these characteristics in order to be able to control the flow of powders but also to be able to control the tribologic phenomena that is, the wear that particles may produce upon the elements with which they come into contact during flow.

2. Research methodology and the used outfits.

This paper has as its first aim applying the methods of study used for metallic powders to food industry powders.

Starting from the fact that the flowing powders are incompressible, dry and rigid we continued by evaluating the flow time for two types of powders.

The samples taken for analysis are two types of flours with different particle size, used daily in bread manufacturing, an essential domain of daily life. The first sample known as sample 1 is a superior quality flour, fine soft, having very small particle sizes. The second, known as sample 2, is a graham type flour, a semolina flour with large particle size. Unloading flours from silos creates great problems due to arching, segregation processes gas accumulations which may produce implosions inside the silos, leading to the contamination of the flour with pieces from the silos' walls. In order to avoid this, we must know the flow properties of powders and the design of the silos should take them into consideration.

The flow behavior for bulk solids has been studied using a combination of Hall flow meter and a Jenike shear cell. This flowmeter is used in accordance with Standard no 3 of the Metallic Powders federation base don 50 g of powder and a flow orifice of 2.5 mm.

The two samples have been subjected to granular separation on a set of sieves with a mesh size of 1000, 630, 500 400 315 212 micrometers and a tray with a diameter of 200 millimeters. The determination of particle repartition is done through the analysis of the sieving, using the set of sieves placed on a magnetic stirrer with a time amplitude of 80 and the functioning time of 10. The particle's fractions distributed on this set of sieves shows like Figure 1.

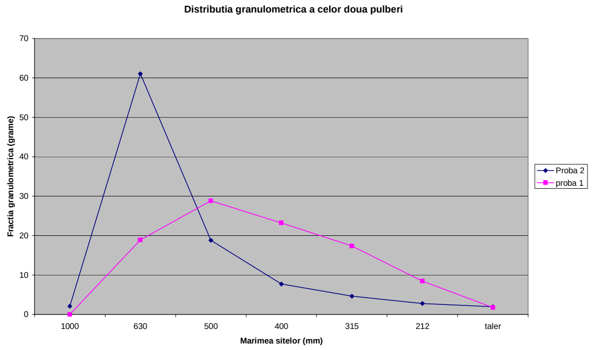

Fig. 1
The particle's fractions distributed

The method is in accordance to the new demands of ISO 9001:2000 for metallic powders.

From the study of these diagrams we may see that sample 1 is dominated by both large and small particles, so we are dealing with a non-homogenous mixture, while sample 2 is dominated by small particles distributed on a small interval.

The steady and controlled flow named flow of bulk solids (flour, sugar, corn flour) from bunkers, silos or other recipients is essential to any mill or industrial enterprise.

Flow interruptions are frequent phenomena due to arching and empty spaces that appear inside flows. Other aspects leading to uncontrolled flows are: segregation of particle mixtures, hardening and aggregation of bulk solids at the segregation locuses, structural failures or the building of an evacuation hole which is smaller than the designed one.

A very important situation appears in the case of bulk solids with small granulation of the sample's 1 type, which was used in the above mentioned experiment, due to the small particle's (smaller than 100 micrometers) strong tendency to adhere. The adhesive forces between particles become stronger and stronger with the growth of the humidity, so that the bulk solid becomes more and more cohesive.

During long-term depositing of flours, they have to be protected against humidity permanently. There is a standard humidity for the flour silos and this has to be respected. The standard humidity accepted for the flour is 14 % and the one accepted for the silo is of 12% maximum. Surpassing these values makes that the water surplus from the flour forms fluid arcs between the particles, thus making the adhesion forces between the particles stronger.

In order to prevent the apparition of uncontrolled flows we must always know the flow properties of bulk solids. We present in this paper the measurement of flow properties for fine particle size bulk solids.

In order to measure the flow properties of a small particle size bulk solids of the type of the flour sample no 1, we used a shearing tester known under the name of Jenike shear cell. As for its design, the tester used for sample no 1, is made from a fix base ring, another ring of the same diameter named superior ring placed on a base ring and a lid.

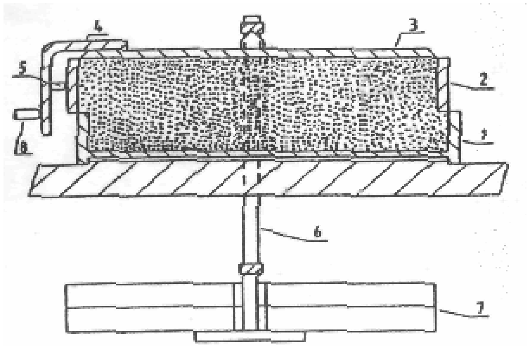

Fig. 2
Jenike shear cell

The structure of the device is presented in Figure 2.

The shearing lid has a bracket and a pin. Before the deformation, ring no 1 is place din equilibrium as in Figure 1, and a vertical force F, which is applied on the lid, acts both on the granular solid inside the cell, through the intermediary of the weight support 6 and the weight 7.

Sample 1 is poured into the shearing cell (figure 2). The cell's lid is placed and the cell is centrally loaded with a normal force N. A bracket connected to an electrical motor through the intermediary of an axle is also connected to the lid. A force transducer is placed between the bracket and the motor, which has the role of measuring the shearing force of the bulk solid from the cell.

The shearing cell's superior part is moved horizontally against the fixed interior ring by a motor driven axle acting on the bracket. The S shearing force exerted on the shearing cell is measured by the transducer. Due to the displacement of the superior ring and of the lid against the inferior ring, the bulk solid is sheared. The normal force σ and the shearing force τ are determined by dividing the normal force N and the shearing force S by the surface A of the shearing cell. The procedure is presented in image 3.

Sample 1 poured into the shearing cell is manually pre-consolidated and then is sheared under the action of the normal force σpres which is adjusted through a normal specific force N. From diagram 5 we may see that the shearing force stress grows with time t. With the growth of the shearing force S we observe a growth of the bulk density of sample 1. After a while we obtain constant values of bulk density and shear stress τ pres. In this case, when the normal force, the shearing force and bulk density are constant we reach the steady flow state.

The values of the normal tension σpres and the shear stress τ pres form the point of steady flow state on the diagram in figure 5.

Once pre-shearing is stopped, powder 1 is again sheared with a reduced normal stress σde<σpres. Because now the solid is sheared with a smaller load than during pre-shear, it will start to flow, in other words it will break. According to Mohr's circle, used to study the flow characteristics of bulk solids, sample 1 begins to flow when the Mohr circle representing the actual stress state reaches the yielding point.

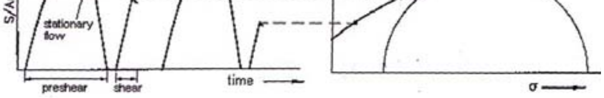

Fig. 3

Plot shear stresses, yield locus

Also in figure 3 we may see that the moment of flow start is marked by a decrease of the bulk density of sample 1 and a considerable decrease of the shearing stress. The maximum from the diagram with the coordinates σ, τ corresponds to the moment when the powder 1 begins to flow. The yielding point is described by the normal and shearing forces. The parameters describing the sample's flow characteristics are determined by the yielding point (σdef, σpres, τdef τpres).

3. Conclusions

From the above mentioned we may conclude the following:

- the flow time and the bulk density are influenced by granular distribution.
- The flow characteristics of a bulk solid are directly influenced by its humidity.
- Creating the flow depends on the pre-shearing stress, on the depositing time of the pre consolidated solid and on bulk density.
- The time of flow for bulk solids having particles of larger dimensions is better than that of bulk solids dominated by particles of smaller sizes because in this case the cohesion force among particles is ore strongly manifested the same as for solids with humidity that exceeds the admitted standard.

4. References

1. *Standard Shear Testing Method for Bulk Solids Using the Jenike Shear Cell,* American Society for Testing and Materials
2. Fălticeanu L. C., I. T. H. Chang, Cook and M. A. Kearns, *Flow Properties of Aluminium based Powders Metallurgy*
3. Fălticeanu L. C., Fălticeanu C. T., Manea M., Ciortan S., *New Methodes for Assesing the Frictional Proprieties of Powders,* Balkatrib, 2005, p. 133-137
4. Arthur Alder, *Flow Properties of Metal powders*, International journal of Powder Metallurgy, 1999, p. 7
5. Fălticeanu L. C., I. T. H. Chang, Fălticeanu C. T., *Researches of the interrelationshiop between powder flow and his characteristics for Aluminium*, Balkantrib, 2005, p. 122/125
6. Schwedes, J., Schulze, D., *Measuring the Fluidity of Bulk Solids and Powders*, 1990

7. Tüzün, U., Abou – Chakra, H., Baxter, J., *A Dem Simulaţion and Experimental Strategy for Solving Fine Powder Flow Problems,* Department of Chemical and Process Enginering, School of Environment, Univrsity of Surrey, Guildfodd, UK, 0ctombrie 2000
8. Jenike, A. W., *Gravity Flow of Bulk Solids*, Utah Engineering Experimental Station University of Utah, Bulletin No .108, 1961
9. Rotaru G., Borda D., Statistic Control in Food Industry, vol I, Academica Publishing House, Galaţi, 2002
10. Pavelescu D. , *Tribology,* vol. I & II, Bucharest Politechnic Institute, 1976
11. Banu C., *The Use, Maintenance and Service of Equipment in Meat Processing Industry* , Technical Publishing House, Bucharest, 1990
12. Iordache Gh, *Equipment for the Construction Materials Industry*, Technical Publishing House, Bucharest, 1987
13. Renert M., *The Calculus and Design of Chemical Equipment*, vol. II, Didactical and pedagogical Publishing House, Bucharest, 1971
14. Jinescu V. , *Equipment for the Processing Industry*, vol. III şi IV, Technical Publishing House, Bucharest, 1989